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Standard Terminology of Symbols and Definitions Relating to Magnetic Testing[1]

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INTRODUCTION

In preparing this terminology standard, an attempt has been made to avoid, where possible, vector analysis and differential equations so as to make the definitions more intelligible to the average worker in the field of magnetic testing. In some cases, rigorous treatment has been sacrificed to secure simplicity and clarity, but it is believed that none of the definitions will prove to be misleading.

It is the intent of this terminology standard to be consistent in the use of symbols and units with those found in IEC 60050-221:1990 International Electrotechnical Vocabulary Chapter 221: Magnetic materials and components. Although Committee A06 has chosen to make SI units normative, the extensive technical and commercial literature using the older Gaussian units requires that many definitions contain discussion about and use of both unit systems. This is not an endorsement of the older unit system and users of this terminology are encouraged to use SI units where possible.

1. Referenced Documents

1.1 *ASTM Standards:*[2]

A343/A343M Test Method for Alternating-Current Magnetic Properties of Materials at Power Frequencies Using Wattmeter-Ammeter-Voltmeter Method and 25-cm Epstein Test Frame

A772/A772M Test Method for AC Magnetic Permeability of Materials Using Sinusoidal Current

2. Terminology

Part 1—Symbols Used in Magnetic Testing

Symbol	Term
a	cross-sectional area of B coil
A	cross-sectional area of specimen
A'	solid area
B	magnetic flux density; magnetic induction
ΔB	excursion range of induction
B_b	biased flux density
B_d	demagnetization flux density
B_dH_d	energy product
$(BH)_{max}$	maximum energy product
B_Δ	incremental flux density
B_i	intrinsic flux density
B_m	maximum value of magnetic flux density in a static hysteresis loop
B_{max}	maximum value of magnetic flux density in a dynamic hysteresis loop
B_r	residual flux density
B_s	saturation flux density
cf	crest factor
CM	cyclically magnetized condition
d	lamination thickness
df	distortion factor
D_m	magnetic dissipation factor
E	exciting voltage
E_1	induced primary voltage
E_2	induced secondary voltage
E_f	flux volts
f	cyclic frequency in hertz
$\mathcal{F}$	magnetomotive force
ff	form factor
H	magnetic field strength
ΔH	excursion range of magnetic field strength
H_b	biasing magnetic field strength
H_{cB}	coercive field strength
H_{cJ}	intrinsic coercive field strength
H_d	demagnetizing field strength

[1] This terminology is under the jurisdiction of ASTM Committee A06 on Magnetic Properties and is the direct responsibility of Subcommittee A06.92 on Terminology and Definitions.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

H_{Δ}	incremental magnetic field strength
H_L	ac magnetic field strength (from an assumed peak value of magnetizing current)
H_m	maximum magnetic field strength in a hysteresis loop
H_{max}	maximum magnetic field strength in a flux-current loop
H_p	ac magnetic field strength (from a measured peak value of exciting current)
H_t	instantaneous magnetic field strength (coincident with B_{max})
H_z	ac magnetic field strength (from an assumed peak value of exciting current)
I	ac exciting current (rms value)
I_c	ac core loss current (rms value)
I_{dc}	constant current
I_m	ac magnetizing current (rms value)
J	magnetic polarization
J_r	residual magnetic polarization
J_s	saturation magnetic polarization
k'	coupling coefficient
ℓ	flux path length
ℓ_1	effective flux path length
ℓ_g	gap length
$\mathcal{L}$ (also φN)	flux linkage
$\mathcal{L}_m$	mutual flux linkage
L	self inductance
L_1	core inductance
L_{Δ}	incremental inductance
L_i	intrinsic inductance
L_m	mutual inductance
L_0	initial inductance
L_s	series inductance
L_w	winding inductance
$\mathscr{m}$	magnetic moment
M	magnetization
M_r	residual magnetization
M_s	saturation magnetization
m	total mass of a specimen
m_1	active mass of a specimen
N	demagnetizing factor
N_1	turns in a primary winding
N_2	turns in a secondary winding
p	magnetic pole strength
$\mathcal{P}$	permeance
P	active (real) power
P_a	apparent power
$P_{a\ (B;f)}$	specific apparent power
P_c	core loss
$P_{c\ (B;f)}$	specific core loss
P_e	eddy current loss
P_h	normal hysteresis core loss
P_q	reactive (quadrature) power
P_r	residual core loss
P_w	winding loss (copper loss)
P_z	exciting power
$P_{z\ (B;f)}$	specific exciting power
Q_m	magnetic storage factor
$\mathcal{R}$	reluctance
R_1	core resistance
R_w	winding resistance
S	lamination factor (stacking factor)
SCM	symmetrically cyclically magnetized condition
T_c	Curie temperature
w	lamination width
W_h	hysteresis energy loss
$\bar{\alpha}$	linear expansion, coefficient (average)
$\Delta\chi$	incremental tolerance
β	hysteretic angle
γ	loss angle
$\cos \gamma$	magnetic power factor
γ_p	proton gyromagnetic ratio
μ_0	magnetic constant
δ	density
κ	susceptibility
ac Permeabilities:	
$\mu_{a,eff}$	rms amplitude permeability
μ_a	amplitude permeability
μ_L	inductance permeability
$\mu_{\Delta}L$	incremental inductance permeability
μ_p	peak permeability
$\mu_{\Delta p}$	incremental peak permeability
μ_i	instantaneous permeability
μ_z	impedance permeability
$\mu_{\Delta z}$	incremental impedance permeability
dc Permeabilities:	
μ	normal permeability
μ	absolute permeability
μ_d	differential permeability
μ_{Δ}	incremental permeability
$\mu_{\Delta i}$	incremental intrinsic permeability
μ_m	maximum permeability
μ_i	initial permeability
μ_r	relative permeability
μ_{rev}	reversible permeability
$\mu'/\cot \gamma$	figure of merit
ν	reluctivity
π	the numeric 3.1416
ρ	resistivity
φ	magnetic flux
φN	flux linkage (see $\mathcal{L}$)
χ	mass susceptibility
χ_0	initial susceptibility
ω	angular frequency in radians per second

Part 2—Definition of Terms Used in Magnetic Testing

active (real) power, *P*—the product of the rms current, *I*, in an electrical circuit, the rms voltage, *E*, across the circuit, and the cosine of the angular phase difference, θ between the current and the voltage.

$$P = EI\cos\theta$$

DISCUSSION—The portion of the active power that is expended in a magnetic core is the total core loss, P_c.

aging coefficient—the percentage change in a specific magnetic property resulting from a specific aging treatment.

DISCUSSION—The aging treatments usually specified for iron and steel are:

(*a*) 100 h at 150°C or
(*b*) 600 h at 100°C.

aging, magnetic—the time dependent change in magnetic properties; such changes can be due to either intrinsic or extrinsic factors, are not a consequence of improper use of the material and are usually detrimental to magnetic performance; in some instances, it may be possible to reverse the effect of magnetic aging via heat treatment or some other process, but typically the benefits are short-lived, and aging will occur again.

DISCUSSION—Two types of magnetic aging can be defined:

(*a*) Intrinsic magnetic aging due to the material as manufactured not being in its thermodynamically stable state so that further microstructural changes occur during service. Such aging is strongly dependent on temperature. The classic example is the aging of iron and electrical steels due to the precipitation of nitrides and carbides. Other examples would include amorphous, nanocrystalline materials and thin films where residual stresses introduced during manufacturing are slowly relieved during service. Ferrofluids show magnetic aging effects due to time dependent degradation of surfactants which results in a settling of the colloidal particles.

(*b*) Extrinsic or environmental magnetic aging due to changes in the magnetic domain structure or microstructure caused by external factors such as mechanical vibration, corrosion, irradiation, service temperature fluctuations, and external magnetic fields. Unlike intrinsic magnetic aging, this type of aging can occur in materials that are otherwise thermodynamically stable.

amorphous alloy—a semiprocessed alloy produced by a rapid quenching, direct casting process resulting in metals with noncrystalline structure.

ampere-turn—the unit of magnetomotive force in the SI system of units.

ampere per metre, A/m—the unit of magnetic field strength in the SI system of units.

NOTE 1—The term ampere-turn per metre has been used as the unit of magnetic field strength. Further use of this term in ASTM standards is deprecated.

anisotropic material—a material in which the magnetic properties differ in various directions.

anisotropy of loss—the ratio of the specific core loss measured with flux parallel to the rolling direction to the specific core loss with flux perpendicular to the rolling direction.

$$anisotropy\ of\ loss = \frac{P_{c\ (B;f)\ l}}{P_{c\ (B;f)\ t}}$$

where:

$P_{c\ (B;f)\ l}$ = specific core loss value with flux parallel to the rolling direction, and

$P_{c\ (B;f)\ t}$ = specific core loss value with flux perpendicular to the rolling direction.

DISCUSSION—This definition of anisotropy normally applies to electrical steels with measurements made in an Epstein frame at a flux density of 15 kG [1.5 T] and a frequency of 60 Hz (see Test Method A343/A343M).

NOTE 2—The IEC defines a similar term called the loss anisotropy factor. It is however calculated differently and is not numerically equal to the above definition.

anisotropy of permeability—the ratio of relative peak permeability measured with flux parallel to the rolling direction to the relative peak permeability measured with flux perpendicular to the rolling direction.

$$anisotropy\ of\ permeability = \frac{\mu_{prl}}{\mu_{prt}}$$

where:

μ_{prl} = relative peak permeability value with flux parallel to the rolling direction, and

μ_{prt} = relative peak permeability value with flux perpendicular to the rolling direction.

DISCUSSION—This definition of anisotropy normally applies to electrical steels with measurements made in an Epstein frame at a flux density of 15 kG [1.5 T] and a frequency of 60 Hz (see Test Method A343/A343M).

antiferromagnetic material—a feebly magnetic material in which almost equal magnetic moments are lined up antiparallel to each other. Its susceptibility increases as the temperature is raised until a critical (Neél) temperature is reached; above this temperature the material becomes paramagnetic.

apparent power, P_a—the product (volt-amperes) of the rms exciting current and the applied rms *terminal* voltage in an *electric* circuit containing inductive impedance. The components of this impedance as a result of the winding will be linear, while the components as a result of the magnetic core will be nonlinear. The unit of apparent power is the volt-ampere, VA.

apparent power, specific, $P_{a(B;f)}$—the value of the apparent power divided by the active mass of the specimen, that is, volt-amperes per unit mass. The values of voltage and current are those developed at a maximum value of cyclically varying magnetic flux density B and specified frequency f.

area, A—the geometric cross-sectional area of a magnetic path which is perpendicular to the direction of the magnetic flux density.

B(H) loop—a hysteresis loop where the magnetic flux density (B) is plotted as a function of the magnetic field strength (H). Unless otherwise stated, it is assumed that the loop represents the SCM condition and therefore has 180° rotational symmetry about the origin of the coordinate system.

B_i(H) loop—a hysteresis loop where the intrinsic flux density (B_i) is plotted as a function of the magnetic field strength (H). Unless otherwise stated, it is assumed that the loop represents the SCM condition and therefore has 180° rotational symmetry about the origin of the coordinate system.

Bloch wall—a domain wall in which the magnetic moment at any point is substantially parallel to the wall surface. See also **domain wall.**

Bohr magneton—a constant that is equal to the magnetic moment of an electron because of its spin. The value of the constant is ($9\ 274\ 078 \times 10^{-21}$ erg/gauss or $9\ 274\ 078 \times 10^{-24}$ J/T).

cgs-emu system of units—the system for measuring physical quantities in which the base units are the centimetre, gram, and second, and the numerical value of the magnetic constant, μ_0, is unity.

coercive field strength, H_{cB}—the absolute value of the applied magnetic field strength (H) required to restore the magnetic flux density (B) to zero.

DISCUSSION—The symbol H_c has historically been used to denote the coercive field strength determined from a $B(H)$ loop. Further use of this symbol in ASTM A06 standards is deprecated.

DISCUSSION—The coercive field strength monotonically increases with increasing maximum magnetic field strength (H_m) reaching a maximum or limiting value termed the **coercivity**. Unless it is known that the material has been magnetized to saturation, the term coercive field strength is preferred.

DISCUSSION—The coercive field strength is not completely described without knowing the maximum magnetic flux density (B_m) or maximum magnetic field strength (H_m) used in the measurement.

coercive field strength, intrinsic, H_{cJ}**—**the absolute value of the applied magnetic field strength (H) required to restore either the magnetic polarization (J) or magnetization (M) to zero.

DISCUSSION—The symbol H_{ci} has historically been used to denote the intrinsic coercive field strength determined from a $B_i(H)$ loop. Further use of this symbol in ASTM A06 standards is deprecated.

DISCUSSION—The intrinsic coercive field strength monotonically increases with increasing maximum magnetic field strength (H_m) reaching a maximum or limiting value termed the **intrinsic coercivity**. Unless it is known that the material has been magnetized to saturation, the term intrinsic coercive field strength is preferred.

DISCUSSION—The measured value of intrinsic coercive field strength will be the same whether it is measured from a magnetic polarization $J(H)$ or a magnetization $M(H)$ hysteresis loop and will always be numerically larger than the coercive field strength (H_{cB}) measured from a magnetic flux density $B(H)$ hysteresis loop.

DISCUSSION—The intrinsic coercive field strength is not completely described without knowing the maximum magnetic polarization, maximum magnetization or maximum magnetic field strength (H_m) used in the measurement.

coercivity—see **coercive field strength**.

coercivity, intrinsic—see **coercive field strength, intrinsic**.

coercivity, normal—this term is used exclusively in the permanent magnet industry to denote the coercivity (H_{cB}) to distinguish it from the intrinsic coercivity (H_{cJ}). The use of the word "normal" does not imply anything about the symmetry of the hysteresis loop of the material being tested.

commutation curve—see **normal magnetization curve**.

core, laminated—a magnetic component constructed by stacking suitably thin pieces of magnetic material which are stamped, sheared, or milled from sheet or strip material. Individual pieces usually have an insulating surface coating to minimize eddy current losses in the assembled core.

core, mated—two or more magnetic core segments assembled with the magnetic flux path perpendicular to the mating surface.

core, powder (dust)—a magnetic core comprised of small particles of electrically insulated metallic ferromagnetic material. These cores are characterized by low hysteresis and eddy current losses.

core, tape-wound—a magnetic component constructed by the spiral winding of strip material onto a suitable mandrel. The strip material usually has an insulating surface coating which reduces interlaminar eddy current losses in the finished core.

core loss, P_c**—**the active power (watts) absorbed in a ferromagnetic or ferrimagnetic material in which there is a time varying magnetic flux density; in electrical steel technology, the core loss is sometimes referred to as the iron loss.

DISCUSSION—Although core loss is almost entirely due to eddy currents generated in the vicinity of moving magnetic domain walls, it is customary to consider the core loss to be the sum of three losses, the **hysteresis loss** (P_h), the **eddy current loss** (P_e), and the **residual core loss** (P_r), all of which have different functional dependencies on frequency for a given material and specimen. This separation of losses is useful in both practical applications and in modeling of the core loss.

DISCUSSION—For the purpose of grading magnetic materials, the core loss is normally measured in the symmetrically cyclically magnetized (SCM) condition using a sine flux waveform, or the results are mathematically corrected for deviations from the sinusoidal condition.

core loss, incremental, $P_{c\Delta}$**—**the core loss in a magnetic material when the material is subjected simultaneously to a dc biasing magnetic field and an alternating magnetic field.

core loss, residual, P_r**—**also called the anomalous or excess loss, the portion of the core loss, P_c, which cannot be attributed to hysteresis or classical eddy current losses.

core loss, specific, $P_{c(B;f)}$**—**the active power (watts) expended per unit mass of magnetic material in which there is a cyclically varying magnetic flux density of a specified maximum value, B, at a specified frequency, f.

core loss density—the active power (watts) expended in a magnetic core in which there is a cyclically varying magnetic flux density of a specified maximum value, B, at a specified frequency, f, divided by the effective volume of the core.

DISCUSSION—This parameter is normally used only for non-laminated cores such as ferrite and powdered cores.

core plate—a generic term for any insulating material, formed metalluriqically or applied externally as a thin surface coating, on sheet or strip stock used in the construction of laminated and tape wound cores.

coupling coefficient, k'**—**the ratio of the mutual inductance between two windings and the geometric mean of the individual self-inductances of the windings.

crest factor, cf**—**the ratio of the peak value of a waveform to its rms value.

DISCUSSION—For a sinusoidal waveform, the crest factor is $\sqrt{2}$.

Curie temperature, T_c**—**the temperature above which a ferromagnetic or ferrimagnetic material becomes paramagnetic.

current, ac core loss, I_c**—**the rms value of the in-phase component (with respect to the induced voltage) of the exciting current supplied to a coil which is linked with a ferromagnetic core.

current, ac exciting, I**—**the rms value of the total current supplied to a coil that is linked with a ferromagnetic core.

DISCUSSION—Exciting current is measured under the condition that any other coil linking the same core carries no current.

current, ac, magnetizing, I_m**—**the rms value of the magnetizing component (lagging with respect to applied voltage) of the exciting current supplied to a coil that is linked with a ferromagnetic core.

current, dc, I_{dc}**—**a steady-state dc current. A dc current flowing in an inductor winding will produce a unidirectional magnetic field in the magnetic material.

customary units—a set of industry-unique units from the cgs-emu system of units and U.S. inch-pound systems and units derived from the two systems.

DISCUSSION—Examples of customary units used in ASTM A06 standards include:

Quantity Name	Quantity Symbol	Unit Name	Unit Symbol
Magnetic field strength	H	oersted	Oe
Magnetic flux density	B	gauss	G
Specific core loss	$P_{c(B;f)}$	watt/pound	W/lb

cyclically magnetized condition, *CM***—**a magnetic material is in a cyclically magnetized condition when, after having been subjected to a sufficient number of identical cycles of magnetizing field, it follows identical hysteresis or flux-current loops on successive cycles which are not symmetrical with respect to the origin of the axes.

demagnetization curve, normal—the portion of a normal hysteresis loop that lies in the second quadrant, that is, between $H = 0$ and the coercive field strength H_{cB}.

demagnetization curve, intrinsic—the portion of an intrinsic hysteresis loop (either B_i, J or M vs H) that lies in the second quadrant, that is, between $H = 0$ and the intrinsic coercive field strength H_{cJ}.

demagnetizing factor, *N***—**the ratio of the self-demagnetizing magnetic field strength to the magnetization (M). It is a dimensionless quantity ranging in value from 0 to 1 and depends on the specimen geometry, dimensions, and the magnetic susceptibility of the material.

DISCUSSION—The demagnetizing factor has a single calculable value only when the sample is an ellipsoid (usually an ellipsoid of revolution) or has the value zero (for a closed uniform magnetic circuit). Approximate values are available as the result of calculations or measurements. For demagnetization factors derived from measurements, one might encounter the symbols N_b for ballistic measurements, N_f for fluxmetric measurements, and N_m for magnetometric measurements. Additional descriptors, used less frequently, define the direction of measurement, that is, N_x, N_y, and N_z.

demagnetizing field strength, H_d**—**a magnetic field strength applied in such a direction as to reduce the magnetic flux density in a magnetized body. See **demagnetization curve.**

density, *δ***—**the ratio of mass to volume of a material. In the cgs-emu system of units, g/cm^3. In SI units, kg/m^3.

diamagnetic material—a material whose relative permeability is less than unity.

DISCUSSION—The intrinsic flux density, B_i, is oppositely directly to the applied magnetic field strength H.

disaccommodation—a time dependent change of magnetic properties, especially the initial permeability, that occurs after demagnetization of a magnetic material. This change is usually due to the motion of point defects such as vacancies and interstitial atoms, occurs over a time period measured in seconds or minutes, and is reversible by demagnetization. It is a different phenomenon than magnetic aging which (*a*) typically involves the clustering of impurity atoms or precipitation of a new phase, (*b*) occurs over a much longer time period (normally weeks or months at room temperature), and (*c*) the changes are not reversible by demagnetization.

dissipation factor, magnetic, D_m**—**the tangent of the hysteretic angle that is equal to the ratio of the core loss current, I_c, to the magnetizing current, I_m. Thus:

$$D_m = \tan \beta = \cot \gamma = I_c / I_m = \omega L_1 / R_1 = I / Q_m$$

DISCUSSION—This dissipation factor is also given by the ratio of the energy dissipated in the core per cycle of a periodic *SCM* excitation (hysteresis and eddy current heat loss) to 2π times the maximum energy stored in the core.

distortion, harmonic—the departure of any periodically varying waveform from a pure sinusoidal waveform.

DISCUSSION—The distorted waveform that is symmetrical about the zero amplitude axis and is most frequently encountered in magnetic testing contains only the odd harmonic components, that is fundamental, 3rd harmonic, 5th harmonic, and so forth. Nonsymmetrical distorted waveforms must contain some even harmonic components, in addition to the fundamental and, perhaps, some odd harmonic components.

distortion factor, *df***—**a numerical measure of the distortion in any ac nonsinusoidal waveform. For example, if by Fourier analysis or direct measurement E_1, E_2 , E_3, and so forth are the effective values of the pure sinusoidal harmonic components of a distorted voltage waveform, then the distortion factor is the ratio of the root mean square of the second and all higher harmonic components to the fundamental component.

$$df = \left[E_2{}^2 + E_3{}^2 + E_4{}^2 + \cdots \right]^{1/2} E_1$$

DISCUSSION—There are no dc components (E_0) in the distortion factor.

domains, ferromagnetic—magnetized regions, either macroscopic or microscopic in size, within ferromagnetic materials. Each domain, in itself, is magnetized to magnetic saturation at all times, and the saturation magnetization is unidirectional within the domain.

domain wall—a boundary region between two adjacent domains within which the orientation of the magnetic moment of one domain changes into a different orientation of the magnetic moment in the other domain.

eddy current—an electric current developed in a material as a result of induced voltages developed in the material.

electrical steel—a term used commercially to designate strip or sheet used in electrical applications and historically has referred to flat-rolled, low-carbon steels or alloyed steels with silicon or aluminum, or both. Common types of electrical steels used in the industry are grain-oriented electrical steel, nonoriented electrical steel, and magnetic lamination steel.

electrical steel, grain oriented—a flat-rolled silicon-iron alloy usually containing approximately 3 % silicon, having enhanced magnetic properties in the direction of rolling and normally used in transformer cores.

electrical steel, nonoriented—a flat-rolled silicon-iron or silicon-aluminum-iron alloy containing 0.0 to 3.5 % silicon and 0.0 to 1.0 % aluminum and having similar core loss in all directions.

emu—the notation emu is an indicator of electromagnetic units. When used in conjunction with magnetic moment, *m*, it denotes units of ergs per oersted, erg/Oe. A moment of 1 erg/Oe is produced by a current of 10 amperes (1 abampere) flowing in a loop of area 1 cm^2. The work done to rotate a moment of 1 erg/Oe from parallel to perpendicular in a uniform field of 1 Oe is 1 erg. The conversion to the SI units of magnetic moment J/T (joule/tesla) or A m^2 is given by:

$$\frac{\text{erg/Oe}\ (\text{cgs} - \text{emu})}{\text{J/T}\ (\text{SI})} \equiv \frac{10\ \text{amperes cm}^2\ (\text{cgs} - \text{emu})}{\text{A m}^2\ (\text{SI})} = 10^{-3} \quad (1)$$

Magnetization, *M*, the magnetic moment per unit volume, has units erg/(Oe-cm^3), often expressed as emu/cm^3.

energy product—the product of the coordinate values of any point on a normal demagnetization curve. This is also called the BH product. In the cgs-emu system of units the energy product is expressed in units of gauss-oersted. In the SI system of units, the energy product is expressed in units of joule per cubic metre.

Discussion—Although the energy product is mathematically negative, it is customary to express it as a positive number.

energy-product curve, magnetic—the curve obtained by plotting the product of the corresponding coordinates, B_d and H_d, of points on the demagnetization curve as abscissa against the magnetic flux density, B_d, as ordinates.

Discussion—The maximum value of the energy product, $(BH)_{max}$, corresponds to the maximum value of the external energy.

Discussion—The demagnetization curve is plotted to the left of the vertical axis and usually the energy-product curve to the right.

energy product, maximum $(BH)_{max}$**—**for a given demagnetization curve, the maximum value of the energy product. The maximum energy product is an important figure of merit for permanent magnets.

equipment test level accuracy—(*1*) For a single test equipment, using a large group of test specimens, the average percentage of test deviation from the correct average value. (*2*) The average percentage deviation from the average value obtained from similar tests, on the same test specimen or specimens, when measured with a number of other test equipments that have previously been proven to have both suitable reproducibility of measurement and test level, and whose calibrations and quality have general acceptance for standardization purposes and where better equipment for establishing the absolute accuracy of test is not available.

exciting current, ac, I—see **current, ac exciting.**

exciting power, rms, P_z**—**the product of the ac rms exciting current and the rms voltage induced in the exciting (primary) winding on a magnetic core.

Discussion—This is the apparent volt-amperes required for the excitation of the magnetic core only. When the core has a secondary winding, the induced primary voltage is obtained from the measured open-circuit secondary voltage multiplied by the appropriate turns ratio.

exciting power, specific, $P_{z(B;f)}$**—**the value of the ac rms exciting power divided by the active mass of the specimen (volt-amperes/unit mass) taken at a specified maximum value of cyclically varying magnetic flux density *B* and at a specified frequency *f*.

exciting voltage, *E***—**the ac rms voltage across a winding linking the flux of a magnetic core. The voltage across the winding equals that across the assumed parallel combination of core inductance L_1, and core resistance, R_1.

feebly magnetic material—a material generally classified as "nonmagnetic," whose maximum normal permeability is less than 4.

ferrimagnetic material—a material whose atomic magnetic moments are both ordered and anti-parallel but being unequal in magnitude produce a net magnetization in one direction.

ferrite—a term referring to magnetic oxides in general, and especially to material having the formula M O Fe_2 O_3, where M is a divalent metal ion or a combination of such ions. Certain ferrites, magnetically "soft" in character, are useful for core applications at radio and higher frequencies because of their advantageous magnetic properties and high volume resistivity. Other ferrites, magnetically "hard" in character, have desirable permanent magnet properties.

ferromagnetic material—a material whose magnetic moments are ordered and parallel producing magnetization in one direction.

figure of merit, magnetic, $\mu'/\cot \gamma$**—**the ratio of the real part of the complex relative permeability to the dissipation factor of a ferromagnetic material.

Discussion—The figure of merit index of the magnetic efficiency of the core in various ac electromagnetic devices.

flux density, biased, B_b**—**the value of the dc magnetic flux density around which cyclic flux density changes are occurring in a magnetic material simultaneously subjected to both a cyclic and a dc biasing field; the biased flux density is a function of the incremental magnetic field strength, H_Δ, and is not determined by the normal magnetization curve.

flux density, demagnetization, B_d**—**the magnetic flux density at any point on any normal demagnetization curve in a magnetic material.

Discussion—Although it is customary to consider the demagnetization curve to lie entirely within the second quadrant, there is an increasing tendency to continue the curve into the third quadrant when measuring high coercivity permanent magnets.

flux density, incremental, B_Δ**—**one half the algebraic difference of the extreme values of the magnetic flux density during a cycle in a magnetic material that is subjected simultaneously to a biasing magnetizing field and a symmetrically cyclically varying magnetizing field; twice the incremental flux density is indicated by the symbol ΔB, thus:

$$B_\Delta = \Delta B/2$$

flux density, intrinsic, B_i**—**the vector difference between the magnetic flux density in a magnetic material and the magnetic flux density that would exist in a vacuum under the influence of the same magnetic field strength when measurements are made using cgs-emu units. This is expressed by the equation:

$$B_i = B - H$$

This term is not defined or used in the SI system of units where the magnetic polarization (J) is instead used. The use of the term intrinsic flux density should be restricted to cgs-emu measurements.

flux density, maximum—*(1)*B_m the maximum value of magnetic flux density, B, in a static hysteresis loop. The tip of this loop has the coordinates B_m and H_m, which occur simultaneously in time. *(2)*B_{max} the maximum value of magnetic flux density, B, in a dynamic hysteresis loop. The tip of this loop has the coordinates B_{max} and H_{max} which may or may not occur simultaneously in time; B_{max} may occur later than H_{max} (especially at low magnetic flux densities).

DISCUSSION—The maximum flux density is not synonymous with saturation flux density (B_s). It is a magnetic test parameter, not a physical property.

flux density, open circuit—the magnetic flux density that remains in a magnetic material in an open magnetic circuit after the applied magnetic field strength is reduced to zero.

flux density, remanent—the magnetic flux density that remains in a magnetic material or magnetic circuit after the applied magnetic field strength is reduced to zero.

DISCUSSION—If there are no self-demagnetizing fields in the magnetic circuit, such as when the circuit is closed, the remanent flux density will equal the **residual flux density**, B_r; if self-demagnetizing fields are present, such as in a circuit with a non-magnetic gap, the remanent flux density will be less than the residual flux density.

flux density, residual, B_r**—**the value of magnetic flux density (B) corresponding to zero magnetic field strength (H) in a symmetrically cyclically magnetized material not subject to a self-demagnetization field.

DISCUSSION—The residual flux density is not completely described without specifying either the maximum magnetic flux density or maximum magnetic field strength used in the measurement. The residual flux density will monotonically increase with increasing applied magnetic field strength reaching a maximum or limiting value.

NOTE 3—This term replaces the historically used term **residual induction**.

NOTE 4—The IEC uses the term remanent flux density instead of residual flux density. The term remanent flux density is used in ASTM standards to denote the magnetic flux density remaining in a magnetic material or circuit when self-demagnetization fields are present.

flux linkage, $\mathscr{L}$**—**the sum of all flux lines in a coil.

$$\mathscr{L} = \varphi_1 + \varphi_2 + \varphi_3 + \cdots \varphi_N$$

where:

φ_1 = flux linking turn 1;
φ_2 = flux linking turn 2, and so forth; and
φ_N = flux linking the Nth turn.

DISCUSSION—When the coupling coefficient, k', is less than unity, the flux linkage equals the product of the average flux linking the turns and the total number of turns. When the coupling coefficient is equal to unity, the flux linkage equals the product of the total flux linking the coil and the total number of turns.

flux linkage, mutual, $\mathscr{L}_m$**—**the flux linkage existing between two windings on a magnetic circuit. Mutual linkage is maximum when the coupling coefficient is unity.

flux path length, ℓ**—**the distance along a flux loop.

flux path length, effective, ℓ_1**—**the calculated length of the flux paths in a magnetic core, which is used in the calculations of certain magnetic parameters.

flux volts, E_f**—**the voltage induced in a winding of a magnetic component when the magnetic material is subjected to repeated magnetization under *SCM* or *CM* conditions.

E_f = $4.443\ B_{max} A' N f \times 10^{-8}$ V (*SCM* excitation)
E_f = $2.221\ \Delta BA'\ Nf \times 10^{8}$ V (*CM* excitation)
E_f = $1.1107\ E_{avg}$

which:

A' = solid cross-sectional area of the core in cm^2,
N = number of winding turns, and
f = the frequency in hertz.

form factor, *ff***—**the ratio of the rms value of a periodically alternating quantity to its average absolute value.

DISCUSSION—For a sinusoidal variation, the form factor is:

$$\pi/2\sqrt{2} = 1.1107$$

frequency, angular, ω—the number of radians per second traversed by a rotating vector that represents any periodically varying quantity.

DISCUSSION—Angular frequency, ω, is equal to 2π times the cyclic frequency, f.

frequency, cyclic, f**—**the number of hertz (cycles/second) of a periodic quantity.

gap length, ℓ_g**—**the distance that the flux transverses in the central region of a gap in a core having an "air" (nonmagnetic) gap in the flux path may be considered unity in the gap.

gauss (plural gausses), G—the unit of magnetic flux density in the cgs-emu system of units. The gauss is equal to 1 maxwell per square centimetre or 10^{-4} tesla. See **magnetic flux density**.

gilbert, Gb—the unit of magnetomotive force in the cgs-emu system of units. The gilbert is a magnetomotive force of 4π/10 ampere-turns. See **magnetomotive force.**

gyromagnetic ratio, proton, γ_p**—**the ratio of the magnetic moment of a hydrogen nucleus to its angular momentum.

DISCUSSION—The gyromagnetic ratio is used to calculate the magnetic field from a measured resonance frequency when using the nuclear magnetic resonance technique. The relationship is:

$$B = (2\pi f/\gamma_p) \text{ gausses} = (2\ \pi\ f\ /\ \gamma_p) \times 10^{-4} \text{ teslas}$$

where:

f = resonance frequency in cycles per second (hertz) and
γ_p = gyromagnetic ratio (the accepted value at present for water is $2.675\ 12 \times 10^4$ $gauss^{-1}\ s^{-1}$).

henry (plural henries), H—the unit of self- or mutual inductance. The henry is the inductance of a circuit in which